45 Sixth Road Woburn, MA 01801 USA Tel: 781 932-0202 Fax: 781 932-3324 www.trexel.com
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MuCell® Applications Guidelines for Injection Molding

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Introduction

The MuCell Process simply makes it easier to produce high quality precision plastics parts. The cost of producing these parts (net of the technology investment) is lower than the costs of producing these parts through conventional molding. In many cases, the quality of the part as defined by warpage, sink, dimensional stability, flatness, or repeatability is higher than the quality of a conventionally molded part.

The most important explanation behind the ability of the MuCell Process to deliver these benefits is the fact that the process permits the *elimination of the pack and hold phase* of the molding cycle. Precision engineering by Trexel of the related equipment and the process itself accomplishes the rest.

The purpose of these *MuCell Sales and Applications Guidelines for Injection Molding* is to help potential users to distinguish between MuCell applications that contribute significant benefits versus other applications which may be considered marginal. Some customers will want to use the process merely to save money through cycle time and material reductions; others will seek to solve quality problems. The MuCell Process changes the fundamental cost/quality relationship of a molded plastics part.

Trexel can support customer mold trials and evaluations worldwide. In its own facilities in Woburn, MA and in the facilities of its technical partner Plastec Wiehl, Germany, Trexel provides direct mold trial support. Mold trial opportunities are available in China, Korea, Singapore, Japan, and many other locations. In addition, many injection molding equipment companies offer MuCell machines of various clamp tonnage and screw sizes. Trexel can assist interested parties in organizing mold trials on this equipment as well. For example, Engel in Austria offers a 1500 ton machine for MuCell trials.

The Value Proposition

There are hundreds of MuCell parts in production today and even more that have been tested and validated. Nonetheless, it is reasonable to assume that new customers will expect to perform their own validations studies.

At the earliest stage of the customer’s evaluation process and in advance of any mold trial, Trexel works closely with potential customers to assist in the definition of their objectives and convert their expectations and requirements into an economic and quality benefits assessment, a so-called “ROI” or “Payback” analysis. If we are able to agree in advance on both the economic value proposition and the definition of a successful mold trial, the evaluation process is simplified for all parties involved.

Direct cost reductions, due to reduced cycle times, lower part weights, and reduced clamp tonnage requirements typically provide the obvious and compelling value proposition. Consistent feedback from many commercial users has emphasized a less obvious but very important economic value: the inherent elimination of molded in stress and sink marks, as well as a more uniform shrinkage which are characteristic of the MuCell process. These traits allow these users to achieve higher quality more quickly and reduce the number of mold iterations and consequent product development delays. Parts are more stable as molded and more likely to remain stable over the long term. These values are maximized by using the MuCell Process from the outset of new programs, since many costly adjustments to mold dimensions can be avoided.

Users have consistently demonstrated that the MuCell Process changes the fundamental cost structure of injection molded components through:

1. The ability to mold flatter, straighter, and dimensionally improved thermoplastic parts, with lower pressures, thereby reducing mold design costs, delays, and scrap rates;
2. Reduced operating costs from cycle time reductions of 20-30%, lower energy consumption, and lower mold pressures;
3. Lower capital costs from the use of smaller and fewer machines, and fewer molds;
4. Reduced material costs from component density reduction, thinner design, and material substitution.

Targeted Applications

Trexel has targeted the following applications areas because Trexel customers have been able to demonstrate a wide range of economic and performance/quality advantages with these products. Of course, this list is not all inclusive and users have developed successful applications across a broad range of industries and applications.

Automotive	Electrical/Electronic
Under Hood and Powertrain Components, air intake manifolds, valve covers	Connector/Socket Components, wire harnesses , wire channels
Electrical/Electronic Components, shift housings, kinematics	Encapsulated Components
HVAC & Radiator Components, end tanks, fans and fan shrouds, valves, and motor covers	Switch Components, junction boxes, fans
Covered Interior Components, door panels, glove boxes, speaker housings	Insert-Molded Products

Targeted Materials

The ultimate goal of the MuCell Process is to produce the molded component with a microcellular structure. This is how the major benefits are achieved with limited loss in mechanical properties. While virtually all polymers will develop a cellular structure, MuCell molders have demonstrated the best results in several families of materials.

All parts using semi-crystalline engineering resins with fillers (PA, PBT, and PET) respond very well to the MuCell Process. Fillers include mica, talc, calcium carbonate, glass fiber, carbon fiber, etc. High temperature materials such as polysulfones and PEEK foam well with the MuCell process.

Unfilled amorphous resins (polystyrene and polycarbonate) tend to yield good reductions in weight and cycle time; however, they also experience relatively higher property loss when weight reductions exceed 10%. The addition of impact modifiers results in slightly lower weight reductions and slightly larger cell structure, which sharply reduces impact strength.

Polypropylene

Trexel has had a great deal of experience with foamed polypropylene products. The ability to derive benefits from the MuCell Process depends greatly on the specific polypropylene application under consideration.

Applications in unfilled polypropylene tend to provide poor results with respect to cycle time, cell structure and property retention. The addition of talc fillers can improve both cell structure and property retention but may or may not result in a reduced cycle time.

In specific instances, polypropylene parts molded with the MuCell process demonstrated advantages which have provided significant cost reductions and quality improvement. When a) the polypropylene resin is filled; b) flatness, warpage, or bow are of very great concern in the application (e.g. boxes, cases, housings, panels); and c) thicknesses are less then 2.5 mm, the MuCell process can allow reductions in cycle time and provide sufficient dimensional compliance to facilitate a material switch or to bring a non-conforming part into compliance with its specifications.

By lowering the viscosity of the resin, the MuCell process permits polypropylene to flow easily over higher L/T (length to thickness) ratios. This phenomenon has allowed Trexel customers to reduce standard thickness of parts by 20-25% (typically, from 2.2 to 1.8 mm.) while permitting the part to be molded under “normal” molding conditions.

Using a rule of thumb of 1 Ton per square inch of clamp tonnage required by the MuCell Process compared to2.5-3 Tons per square inch required in a solid molding process, very significant economic benefits can be obtained on large parts through the use of smaller molding machines . In recent examples, MuCell has helped customers reduce their machine tonnage requirements from 3,000 tons to 1,900 tons.

Trexel has made particular advances in the processing of long glass fiber PP with special process and equipment modifications which help retain fiber length while reducing or eliminating warpage.

Managing Materials Reductions and Evaluating Material Substitutions

A MuCell implementation strategy based solely on materials reduction will usually be unsuccessful because it will fail to provide a sufficient value proposition on its own. In the first place, maximum achievable materials reduction is controlled by the shape of the mold and, in particular, the L/T (length to thickness) ratio within the mold. As pressures build, foaming is reduced or compressed.

Secondly, material reductions greater than 10-15% usually reduce properties significantly, making it difficult to be certain that the final performance of the parts will be acceptable to the customer. Therefore, Trexel recommends that the economic benefit be modeled on an achievable weight saving of 8-12%. If greater savings are ultimately achieved, it will be a bonus to the customer and there are many such examples.

However, in some instances, the combination of viscosity reduction and/or warpage reduction facilitates the substitution of a lower grade material for a higher grade material. The best examples of this opportunity involve electrical connectors where it has been shown repeatedly that solid parts molded in Questra or LCP can be molded as MuCell connectors using PBT's and nylons. Similar results have been obtained with the substitution of filled polypropylenes for Noryl's where the control of warpage is the dominant criterion in the selection of the material.

Whereas weight reduction achieved strictly through foaming will be normally in the 8-12% range, the use of the MuCell process dramatically changes the design rules that govern the design of plastics parts. With the improved viscosity, absence of pack pressure, and elimination of sink marks and non uniform stress, new design windows are opened which facilitate part weight savings as high as 30% through a combination of new design approaches which exploit the MuCell design freedoms plus foaming.

MuCell as a Problem Solving Technology

MuCell molding provides step change improvement in parts quality where non-uniform shrinkage, flatness, concentricity (out of roundness), or cavity pressure affect parts quality.

The MuCell process eliminates or reduces molded-in stress, which often is the root cause of warpage in the part. This effort in solid molding typically results in excessive cycle time or chronic quality issues, which decrease yields. MuCell immediately eliminates stress-induced warpage, at virtually any weight reduction, allowing for the production of parts that start flat and remain flat even through heat cycles. This has been demonstrated in many applications including a printer chassis made of a filled PPO/PS blend where 1.75 mm deflections were reduced to 0.75 with no mold changes, and high-precision carrier trays made of a carbon fiber-filled polycarbonate where deflection was reduced from 0.7 mm to 0.15 mm.

Our commercial users consistently point to the reduction of plastic pressures in the mold as an important factor in other problem solving as well. For instance, lower pressure are critical when a film or fabric is placed in the mold and the plastic is injection molded behind the decorative coverstock, or when an electrical component must be encapsulated. In these instances, excessive pressure (and heat) from the plastic or high cavity pressure can damage the coverstocks or the components. At the same time, the MuCell Process can eliminate issues associated with sink marks, thus further improving parts quality.

The lower cavity pressure comes from two distinct sources: reduced melt viscosity and the minimizing of the cavity packing phase. While the elimination of packing and molded in stress has perhaps attracted the greatest industry interest, the inherent reduction in melt viscosity associated with the process, has also demonstrated significant technical improvements on its own. For example, experiments have been done on cell phone cases where it was not previously possible to fill the mold using a polycarbonate material at the required high processing temperature of 290° C. However, the viscosity-reducing affects of the MuCell Process made it possible to fill the mold with the polycarbonate resin at the 290° C while reducing cavity pressure from 620 bar (9000-psi) to less than 300 bar. Of course, molded in stresses were also significantly reduced.

The temporary change in polymer morphology, which causes the reduced viscosity of the polymer melt also provides a unique benefit with semi crystalline materials such as PBT and Nylon. Equal levels of crystallinity, which is often associated with maximum physical properties can typically be achieved with lower mold and melt temperatures. Many commercial users are exploiting this trait to optimize cycle times reduction.

Applications to Avoid

Applications that require transparency are not possible.

Customers with applications that require a very high-quality surface finish have been advised in the past not to attempt MuCell Molding or to expect more complex process development and mold modifications in order to optimize surface appearance. Such development has usually entailed careful attention to mold surface and the use of texturing as well as the development of a process that uses different injection speeds (profiling).

The limitation of surface appearance is gradually being addressed by Trexel and today certain specially designed materials grades such as PA 6 and PA 6,6 are available which inhibit the development of splay and which provide good surface appearance.

Conclusion

In many cases, the suitability of the MuCell Process can be predicted. In order to support customers in the most efficient manner possible, it is essential to QUALIFY the intended application. This qualification process must determine the answer to the basic question:

What is the expected value of the MuCell Process to the customer ?

A clear upfront hypothesis will provide the most satisfactory solution to all parties.

Trexel Sales Managers in Europe, North America, Asia and Japan will be happy to assist our prospective customers, partners and current customers in assessing the suitability of the MuCell Process for their requirements.

Region	Contact	Email	Phone
Europe	**Dr. Hartmut Traut Wiehl, Germany**	**h.traut@trexel.com**	**+49-172-270-3028**
Asia	**Patrick Tong Hong Kong**	**p.tong@trexel.com**	**+852-917-97015**
Japan	**Yasuhide Sunamura Yokohama**	**trexeljapan@triton.ocn.ne.jp**	**+81-457-218481**
North America	**Cathy Ferrel Royal Oak, MI**	**c.ferrel@trexel.com**	**+1 248-584-3800**
Trexel	**David Bernstein Woburn, MA**	**d.bernstein@trexel.com**	**+1 781-932-0202 Ext.239**